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Research

Materials Science Research Opportunities within the Biological and Physical Research Enterprise

MU-SPIN Presentation

November 12, 2003

Frank R. Szofran, Ph.D.

Researcher in Residence

Educational Outreach

OBPR Organization

OFFICE OF BIOLOGICAL AND PHYSICAL RESEARCH (Code U)

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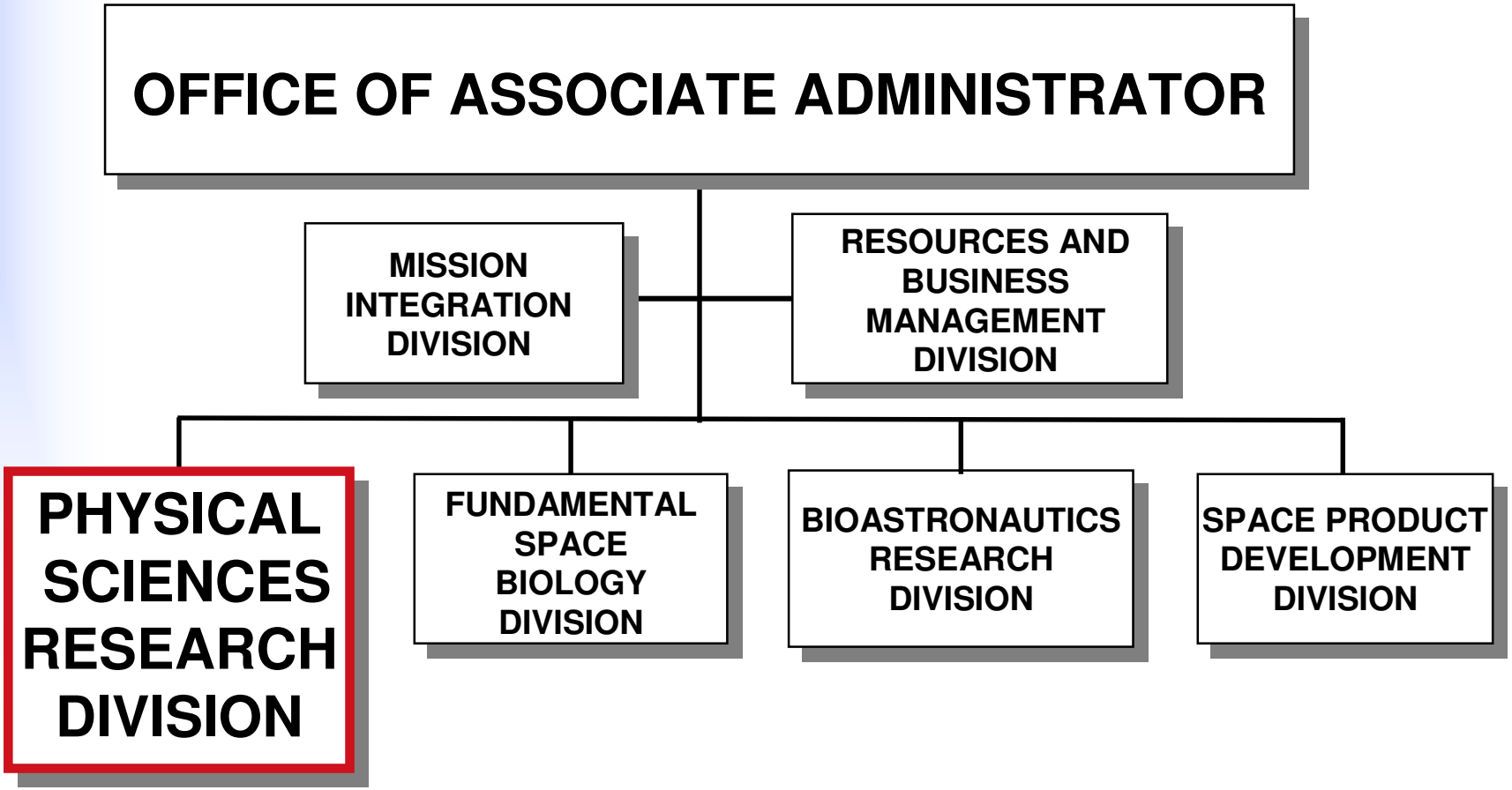

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Discussion Points

- OBPR Alignment with NASA Vision and Mission
- OBPR Organizing Questions
- Current Areas of Emphasis within Materials Science
- Physical Sciences Research Division (PSRD) NASA Research Announcements
- Roadmap for Materials Science within the PSRD
- Administration of Materials Science grants

NASA Vision and Mission

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NASA's Vision

To improve life here,

To extend life to there,

To find life beyond.

NASA's Mission

To understand and protect our home planet

To explore the Universe and search for life

To inspire the next generation of explorers

…as only NASA can.

OBPR Organizing Questions

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Five organizing questions are the basis for the Biological and Physical Research Enterprise Strategy:

1. **How can we assure the survival of humans traveling far from Earth?**
2. **How does life respond to gravity and space environments?**
3. **What new opportunities can research bring to expand understanding of the laws of nature and enrich lives on Earth?**

OBPR Organizing Questions

4. **What technology must we create to enable the next explorers to go beyond where we have been?**
5. **How can we educate and inspire the next generation to take the journey?**

The answers to these questions determine our research strategy, the platforms or programs to execute the science, applications for the research, and the metrics to measure progress.

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Physical Science Research Theme

- Physical Science Research includes basic and applied research to:
  - Exploit space to pursue basic research questions in biotechnology, combustion science, materials science, fluid physics, and fundamental physics
  - Improve spacecraft systems for energy storage and management; for propulsion using advanced materials engineering; for preventing, detecting, and suppressing fire; for more efficient life-support; and for mitigating radiation impact
  - Advance fundamental scientific understanding to improve industrial processes

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Physical Science Research Theme: Relevance to NASA Mission

- To understand and protect our home planet
  - Research outstanding problems relevant to improved technologies, particularly addressing novel, high value-added products
  - Develop technologies for cleaner, more efficient utilization of energy sources

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Physical Science Research Theme: Relevance to NASA Mission

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- To Explore the Universe and search for life
  - Probe the fundamental laws of the universe directly through definitive critical experiments enabled by the microgravity environment
  - Prepare the way for human exploration through space technology development
  - Evaluate the role of gravity in complex inert and living systems

Physical Science Research Theme: Relevance to NASA Mission

- To inspire the next generation of explorers
  - Support human presence in space
  - Promote direct student participation in flight research
  - Contribute new knowledge of the universe

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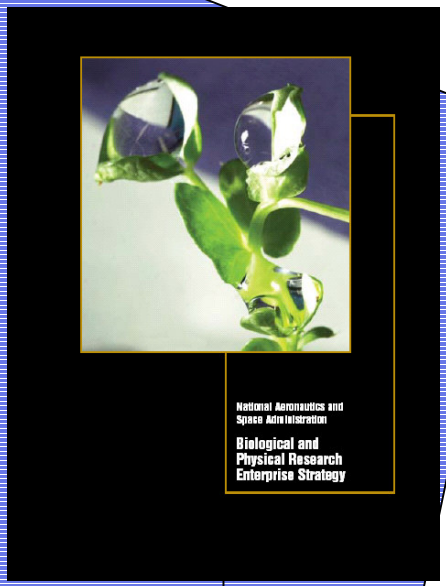
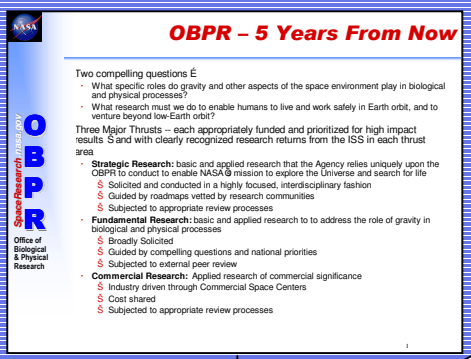
Planning Framework

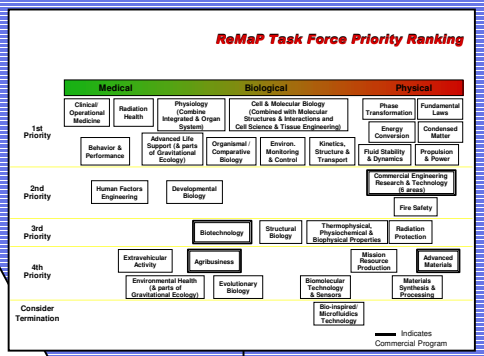
BPR Enterprise Strategy



5-Year Vision



ReMAP

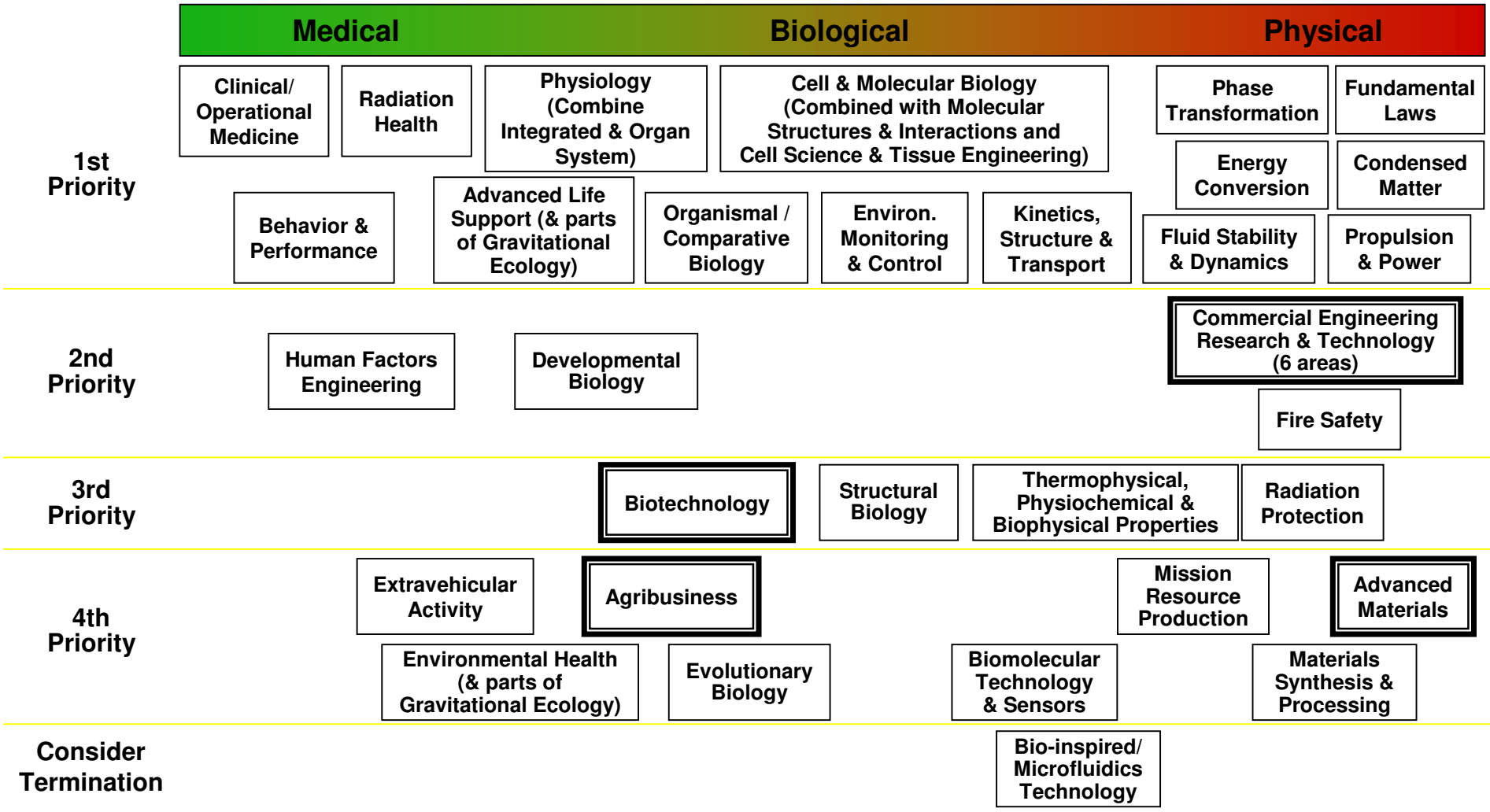


Now

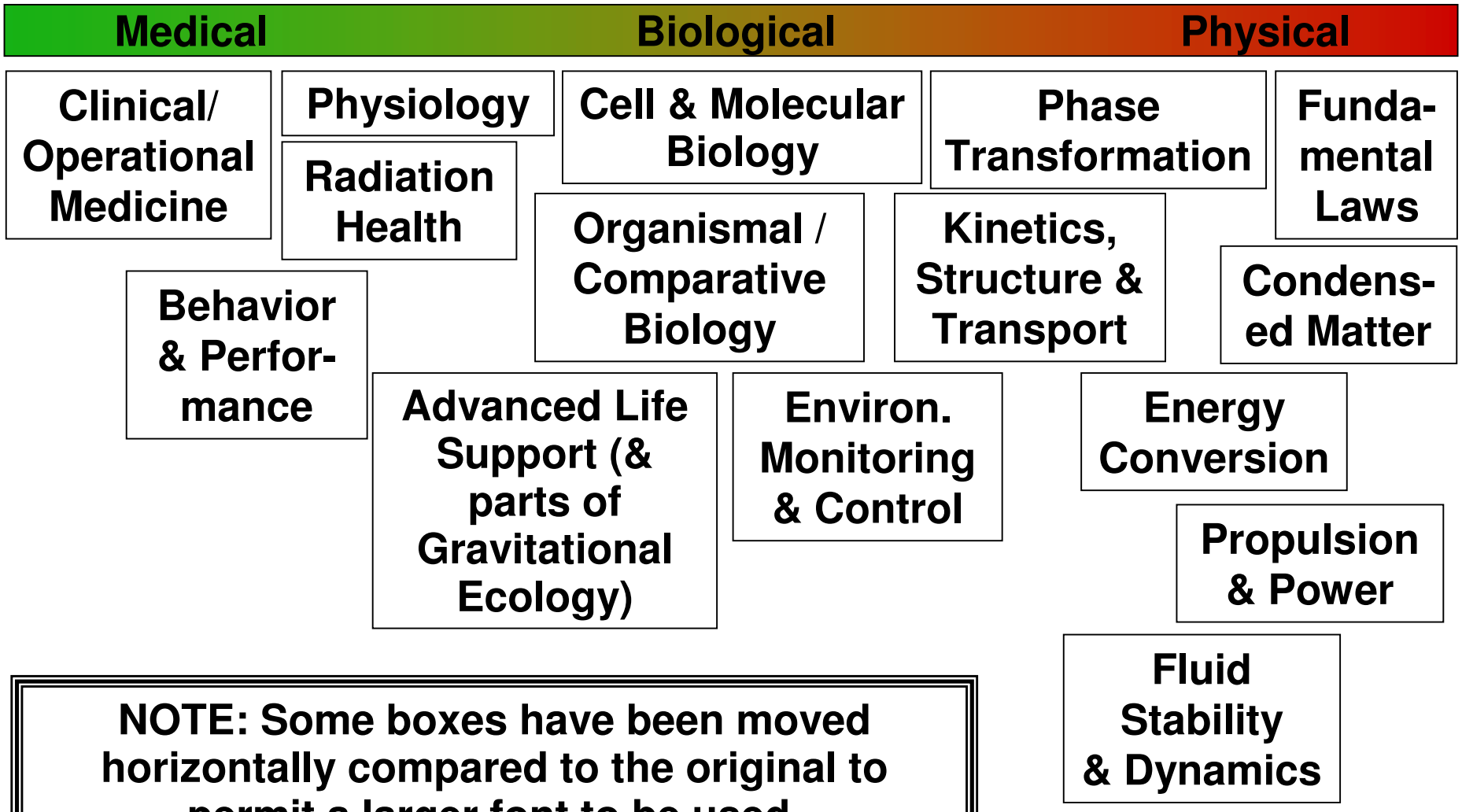
5 Years

10 years

ReMaP Task Force Priority Ranking



The Highest ReMaP Priorities



NOTE: Some boxes have been moved horizontally compared to the original to permit a larger font to be used.

OBPR – 5 Years From Now

- Two compelling questions…
  - What specific roles do gravity and other aspects of the space environment play in biological and physical processes?
  - What research must we do to enable humans to live and work safely in Earth orbit, and to venture beyond low-Earth orbit?

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OBPR – 5 Years From Now

- **Three Major Thrusts --**
  - **Strategic Research:** basic and applied research to enable NASA's mission to explore the Universe and search for life
  - **Fundamental Research:** basic and applied research to to address the role of gravity in biological and physical processes
  - **Commercial Research:** Applied research of commercial significance

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OBPR 5 Years From Now

- Stronger, more diverse investigator community
  - Providing excellent training opportunities for the next generation
- Outreach and education receive at least 2% of OBPR budget
  - Integral connection to research programs
  - Effective education efforts and enhanced public awareness and support
- Strong partnerships with other government agencies, international partners, and the industrial and academic communities

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Materials Science for Exploration

- **Key space propulsion materials needs for Advanced Space Transportation Program elements have been identified.**

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Materials Science for Exploration

- **Basic materials science research topics have been defined and prioritized**
  - Enabling Materials
    - Flight Weight Magnets, Nuclear Fuels and Materials, Materials for Radiators, Thrusters, and Solar Sails; Materials with High Specific Strength/Stiffness
  - Enabling Processes
    - Self-Assembly and Self-Organization
  - Research Enabled by Access to Space Environment
    - Free-Form Fabrication
  - Establishment of Cornerstone Knowledge
    - Prediction and Verification of Materials Properties

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Materials Science Research: Solicitation, Selection, and Execution

- How can access to microgravity benefit materials science research?
- What are we currently doing in the program?
- How will we do materials science research on the space station?
- How does the NASA Research Announcement (NRA) Process work?

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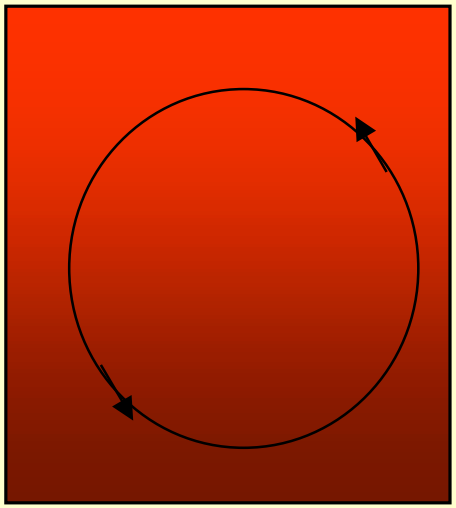
Potential Beneficial Effects of Reduced Gravity for Materials Science Research

Reduces or Eliminates Buoyancy Driven Convection (1)



- Suppresses Thermal and Compositional Fluctuations
- Eliminates Unwanted Mixing
- Simplifies or Allows Precise Measurement of Thermophysical Properties

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Reduces or Eliminates Buoyancy Driven Convection (2)

- Vastly simplifies the Evaluation of the Importance of the Various Heat and Mass Transport Processes
- Allows the Determination of Subtle Non-Gravity Related Phenomena, e.g., Surface Tension Gradient-Driven Flow Effects
- Aids in the establishment of Diffusion-Limited Conditions

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Potential Beneficial Effects of Reduced Gravity for Materials Science Research

Reduces or Eliminates Sedimentation

- Facilitates Heterogeneous Mixtures or Suspensions
- Reduces or Prevents Unwanted Phase Separation
- Allows Enhanced Containerless Solidification Processes

Coarsening in lead-tin

Prof. Voorhees, Northwestern University

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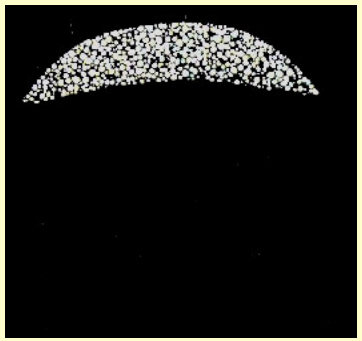
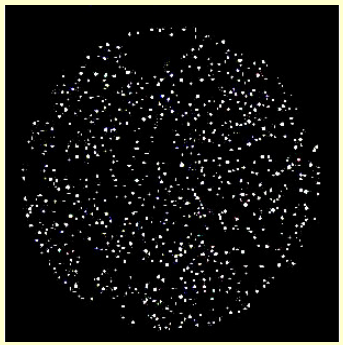


tin phase floating



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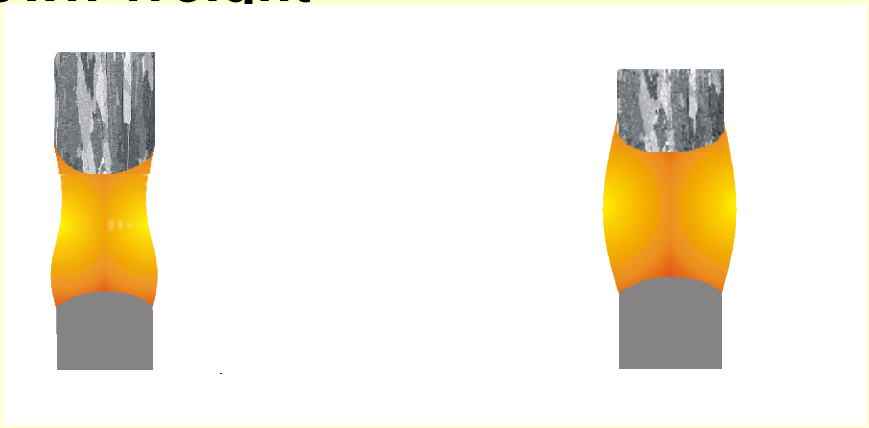
even distribution, shuttle flight STS-83

Permits quantitative measurements

Eliminates Hydrostatic Pressure

- Facilitates the Containment of Liquids by their Surface Tension
- Allows Float Zone Processing of Low Surface Tension Materials
- Eliminates or Reduces Stresses Arising from the Material's own Weight



Schematic of float zone processing

NASA's Materials Science Program

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Materials Science is viewed as study themes and as classes of materials

- Classes of materials
  - Electronic and photonic, metals and alloys, biomaterials, glasses and ceramics, nanostructures/self-assembly, polymers, and composites
- Themes
  - Prediction and control of microstructures, nucleation and metastable states, transport phenomena, phase separation and interfacial phenomena, crystal growth and defect generation, crew health and safety, and in situ resource utilization

Materials Science NASA Research Announcement

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Schedule for Research Proposals

- NRA Release: January 2004
- Proposals Due: Fall 2004
- Reviews: Spring/Summer 2005
- Selections: Summer/Fall 2005

All dates are estimates and are subject to change.

Materials Science NASA Research Announcement

- **Ground based research (1 of 2)**
  - Provides the intellectual underpinnings of the flight program
  - Supports NASA's Missions
    - –Coordination with the other NASA Enterprises
  - Experimental and theoretical

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Materials Science NASA Research Announcement

- **Ground based research (2 of 2)**
  - Well articulated Microgravity/NASA relevance
    - Demonstration of the role of gravity; benefits to be accrued from conducting research in microgravity
    - Support for the Microgravity Materials Science Program
    - Support for NASA's Exploration Mission
  - Funding for up to 4 years
  - Average $100k/year

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Materials Science NASA Research Announcement

- Flight experiments
  - High scientific and technical merit
  - Well articulated need for a long duration, high quality microgravity environment
  - Experimental and theoretical maturity to support a Science Concept Review within approximately two years

What's Required in the NRA Proposal?

- A cover page format with budget summary information that *must* be used.
- A standard budget format that *must* be used.
- The budget detail for subcontracts is the same as that required for the Principal Investigator and Co-Investigators.
- Those that are seeking renewal *must* provide a summary (3-4 pages) of results from the current research. There *must* be a discussion of the Microgravity/NASA relevance.

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NRA Review Process

- Panels: proposals grouped by common theme
- Proposals are initially read and evaluated by at least three reviewers
- Scoring is by panel consensus: It is the score of the panel, not individuals.
- Significant emphasis on scoring consistency

Advice from the Reviewers

- Reviewers appreciate clear and concise writing.
- Reviewers will not “read between the lines.”
- Appendices and supplementary material should be added judiciously.

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Advice from the Reviewers

- Reviewers expect proposals written within the designated guidelines that provide the information required for evaluation.
- Collaboration: Multiple Proposals vs. Long, High Budget Proposals
  - Reviewers typically preferred separate proposals where clear indication was given to collaboration with other proposers.
  - Reviewers opined that large, expensive proposals were difficult to evaluate.

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Materials Science Roadmap

- **Most Materials Science research will be related to Organizing Question 3.—What new opportunities can research bring to expand understanding of the laws of nature and enrich lives on Earth?**
- **Some is related to Question 1**
- **Complete roadmaps for all organizing questions are in the OBPR strategy document**

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Materials Science Roadmap

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Organizing Question 3.—What new opportunities can research bring to expand understanding of the laws of nature and enrich lives on Earth?

Research Targets	Today	2004-2008	2009-2016
Determine how space environments change physical and chemical processes	Research hampered by gravity-driven effects; gravity effects not understood in many Technologies	Conduct ground and flight research to develop and validate models for fluid, thermal, combustion, and solidification processes	Test extended range models for heat transfer and microfluidic control, turbulent and high-pressure combustion validation; nanotechnology-based materials with enhanced and adaptive properties
Understand how structure and complexity arise in nature	Limited experimental data collected on self-assembly, self-organization, and structure development Processes	Conduct ground and space research in solidification dynamics, colloidal photonics, carbon Nanostructures	Research new technologies for advanced photonic materials Test solidification models using industrial systems Conduct flight investigations in turbulent combustion, granular material systems, and flows

Complete roadmaps for all organizing questions are in the OBPR strategy document.

Administration of Materials Science Grants

- The process of selecting NRA proposals for funding is carried out by NASA Headquarters personnel.
- After selection, most Materials Science grants are administered for OBPR at the Marshall Space Flight Center (MSFC).
- Centers which administer grants for OBPR employ a cadre of scientists to serve as Project Scientists to enable NASA to be a “smart buyer” of research and hardware.

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Administration of Materials Science Grants

- OBPR scientists compete on a level playing field with non-NASA scientists. Competing OBPR scientists have no connection with or insight into the selection process.
- Collaboration among NASA and non-NASA scientists on NRA proposals is strongly encouraged.
  - PI can be a NASA or a non-NASA scientist
  - Research teams are typically completed during proposal preparation with little possibility of adding team members after selection

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Summary

- OBPR has developed and published a long term vision and strategy available at spaceresearch.nasa.gov/docs/OBPRStrategy.pdf
- Strategic research is receiving significant emphasis within OBPR and PSRD
- Materials science research focused on in-space propulsion and in-space manufacturing and repair will establish the foundation that supports PSRD transition to strategic research portfolio and addresses OBPR strategic goals.